POST- INSTALLED ANCHORS IN CONCRETE

IR 19-1

Discipline: Structural
References:
2001 California Building Code, Sections 1912A.1 and 1923A.3.5
ICC ES Acceptance Criteria AC-01, AC-58, AC-193 including Annex 1, AC-106, AC-308, and AC-70
ACI 355.2 or ACI 318-02, Appendix D

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This Interpretation of Regulation (IR) is intended for use by the Division of the State Architect (DSA) staff, and as a resource for design professionals, to promote more uniform statewide criteria for plan review and construction inspection of projects within the jurisdiction of DSA, which include State of California public elementary and secondary schools (grades K-12), community colleges, and state-owned or state-leased essential services buildings. This IR indicates an acceptable method for achieving compliance with applicable codes and regulations, although other methods proposed by design professionals may be considered by DSA.

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Code Section: ***1923A.3.5 Drilled-in expansion bolts or chemical-type anchors in concrete.*** *When drilled-in expansion-type anchors are used in lieu of cast-in place bolts, the allowable shear and tension values and test loads shall be acceptable to the enforcement agency.*

When expansion-type anchors are listed for sill plate bolting applications, 10 percent of the anchors shall be tension tested.

When expansion-type anchors are used for other structural applications, all such expansion anchors shall be tension tested. Expansion-type anchors shall not be used as hold-down bolts.

When expansion-type anchors are used for nonstructural applications such as equipment anchorage, 50 percent or alternate bolts in a group, including at least one-half the anchors in each group, shall be tension tested.

The tension testing of the expansion anchors shall be done in the presence of the project inspector and a report of the test results shall be submitted to the enforcement agency. If any anchors fail the tension-testing requirements, the additional testing requirements shall be acceptable to the enforcement agency. The above requirements shall also apply to bolts or anchors set in concrete with chemical (adhesives) if the long-term durability and stability of the chemical material and its resistance to loss of strength and chemical change at elevated temperatures are established to the satisfaction of the enforcement agency.

Purpose: This interpretation establishes the allowable shear and tension values, testing procedures and test values for post-installed anchors, including a new product line known as screw anchors, in accordance with Section 1923A.3.5, 2001 CBC for projects under the jurisdiction of the Division of the State Architect (DSA).

1. LISTING REQUIREMENTS: Post-Installed anchors must be listed in a current evaluation report issued by an evaluation agency recognized by DSA, which include the following:

- International Code Council Evaluation Service (ICC-ES)
- City of Los Angeles Research Report (RR)

Commentary: *ICC-ES Evaluation Reports are generally considered to be current if they are listed and available from the ICC website http://www.icc-es.org/reports/index.cfm?search=search*

2. BASIS FOR DESIGN CAPACITIES: Design capacities for expansion-type and epoxy (adhesive)-type anchors should reflect the tested capacity of the anchors including the degree of scatter in the recorded peak loads and the load-displacement response, the type and mechanical properties of the concrete or masonry in which the anchor is installed, anchor edge distance and spacing, and whether the anchors are installed through metal decking into concrete fill. In addition, the potential for concrete cracking in the vicinity of the anchor during its service life and the effect of such cracking on the capacity of the anchor to resist loads shall be considered. The effects of temperature variations on epoxy (adhesive) type anchors shall also be taken into account where applicable.

The age, composition and mechanical properties of the materials in which the anchor will be installed shall be evaluated. The relevant mechanical properties include unit weight, compressive strength, and aggregate size and type. Evaluation of compressive strength on the basis of cores taken at or near the anchor locations shall be permitted.

Exception: The design capacities for anchors tested in lightweight concrete may be used for anchors installed in normal-weight concrete provided the compressive strength of the normal-weight concrete equals or exceeds the compressive strength of the lightweight concrete in which the anchor was tested. Furthermore, design capacities for anchors tested in all-lightweight concrete (unit weight 90-115 pcf) may be used for anchors installed in sand-lightweight concrete (unit weight 105-120 pcf) provided that the compressive strength of the sand-lightweight concrete equals or exceeds that of the all-lightweight concrete in which the tests were conducted.

The compressive strength of the material in which the anchor will be installed shall meet or exceed the compressive strength of the material in which the anchor was tested.

2.1 Expansion-type anchors. Expansion-type anchors may be used, provided the allowable shear and tension loads are determined by test in accordance with the following:

2.1.1 The allowable values listed in an ICC-ES Evaluation Services Report, with special inspection, may be used for allowable stress design, provided the report states that the anchors were tested in accordance with AC01, latest revision, including the seismic qualification tests of AC01 Section 5.6. Strength design values may be used provided the anchors have been tested in accordance with AC193, latest revision, including the seismic qualification tests of ACI 355.2 Sections 9.6 and 9.7 and Annex 1 of AC193.

Commentary: *The ICC-ES Reports generally allow the use of the 33-1/3% stress increase for duration of loading if the anchor(s) have satisfied the seismic qualification testing criteria. Section 1632A.1, 2001 CBC, precludes the use of the stress increase in determining capacities of some anchorages.*

For anchors installed in the underside of a beam/slab, the allowable tension load design values should be based on the tabulated value for the anchors installed without special inspection (special inspection is still required), unless allowable load values for anchors installed in cracked concrete are provided in the ICC-ES Report, or the anchors have been tested in accordance with ACI 355.2, latest

revision, Table 5.2 and Annex 1 of AC-193, or ACI-318-05 Appendix D. Shear values are based on the tabulated values in the ICC-ES Report. Once an ICC-ES Report complying with AC-193 has been issued, it shall take precedence over any previous report.

Commentary: Once a report is issued that complies with the provisions of AC-193, the values established by that report take precedence over previous reports. Provisions of AC-193 will provide the most accurate evaluation of anchor capacities in various installed conditions. The use of older reports, which may have provided for higher capacities, is not appropriate once the AC-193 compliant report has been published.

2.1.2 If anchors have not been tested in accordance with the requirements for seismic qualification tests of AC01, Section 5.6, the allowable load values listed in the ICC-ES Report may be used with the following modifications.

2.1.2.1 Allowable shear and tension design loads shall be limited to 80% of the tabulated allowable values for anchors installed with special inspection.

2.1.2.2 For anchors installed in the underside of a beam/slab, the allowable tension load should be based on 80% of the tabulated allowable value for anchors installed without special inspection (special inspection is still required). Allowable shear values should be based on Section 2.1.2.1 above.

Exception: Anchors installed in conformance with requirements of Section 4 of this IR.

Commentary: Previous Interpretations of Regulations have allowed the submittal of test data by anchor manufacturers for review and acceptance by the DSA. Given the complexities of ICC-ES Acceptance Criteria, and the volume of data that can be submitted, it is no longer feasible for the DSA to evaluate products without a current ICC-ES Report.

2.2 Epoxy-type anchors. Epoxy-type (adhesive) anchors include anchors that rely on organic and inorganic compounds (including epoxies, polyurethanes, methacrylates and vinyl esters) to develop the bond to the concrete.

The use of shallow epoxy-type (adhesive) anchors to resist direct tension loads where concrete cracking may occur is not permitted. Shallow epoxy-type (adhesive) anchors are those with an embedment to diameter ratio less than 8.

Commentary: Laboratory testing has shown that the tension performance of epoxy-type (adhesive) anchors in cracked concrete can be significantly reduced. This is particularly true of small diameter and shallow embedment anchors. In the absence of recognized testing criteria for establishing the performance of epoxy-type (adhesive) anchors in cracked concrete, their use shall be restricted.

Epoxy-type (adhesive) anchors should only be installed in conditioned, interior spaces.

Commentary: This limitation is due to the absence of test results demonstrating long-term durability of the adhesives when exposed to numerous cycles of either high or low temperatures and the ability of the anchor to resist loads when either the adhesive or a bolt is exposed to weather to transfer the heat/cold to the adhesive.

Exception: Where epoxy-type anchors are used as shear dowels at the perimeter of an existing opening (slab or wall) to be filled with concrete, or are being used to connect new concrete elements to existing concrete

elements (e.g. gunite), they may be installed in exterior locations with prior approval of the DSA.

Commentary: *DSA has ongoing concerns regarding long-term durability of the adhesives when exposed to numerous cycles of either high or low temperatures and the ability of the anchor to resist loads when either the adhesive or a bolt is exposed to weather to transfer the heat/cold to the adhesive.*

If epoxy-type (adhesive) anchors are exposed to fire, all anchors in the affected area shall be inspected and evaluated by a qualified person to ensure their load carrying capability has not been compromised.

The design shear and tension capacities for epoxy-type anchors must be determined in accordance with the following:

2.2.1 The allowable loads may be based on the values listed in an ICC ES Report that complies with the requirements of AC58 for a specific anchor in the same configuration as tested. Supporting data shall include the Seismic Qualification test performed in accordance with the procedures of Section 5.3.7 of AC58.

Commentary: *As strength level capacities are developed to meet ACI 355.2, or ACI 318 Appendix D provisions, those capacities should be based on the capacities either listed or determined in accordance with the ICC ES Report.*

2.2.2 Where epoxy-type (adhesive) anchors are used for structural applications, such as dowels between new and existing concrete, the anchors shall be installed in a manner such that the ultimate tensile capacity is controlled by the ultimate strength of the steel element.

Exception: Epoxy-type (adhesive) anchors which cannot develop the tensile capacity of the steel element may be used to transfer shear forces only, provided that the loads on the anchor are amplified by factor of 4.0. Alternatively, allowable shear capacity may be based on bolt shear capacities obtained from Table 19A-D, 2001 CBC.

When epoxy-type (adhesive) anchors are used to resist tensile forces in structural applications, the minimum depth of embedment shall be greater than or equal to the development length, l_d, determined in Section 1912A.1 for a cast-in-place reinforcing bar of the same diameter and grade when considering a tensile splitting failure mode. Where tensile splitting need not be considered, the depth of embedment may be determined in accordance with Appendix D of ACI 318-02 as amended by Section 3.3 of AC 308.

2.3 Screw Anchors. Screw anchors are not directly addressed by Section 1923A.3.5, 2001 CBC. The fastener is produced from hardened steel with threads, similar in appearance to a lag bolt. Screw anchors may be used, provided the allowable shear and tension loads are determined in accordance with the following:

2.3.1 The allowable values listed in an ICC ES Report, with special inspection, may be used for allowable stress design, provided the report states that the anchors were tested in accordance with AC106, latest revision, including the seismic qualification tests of AC106 Section 4.6.

Commentary: *As strength level capacities are developed to meet ACI 355.2, or ACI 318 Appendix D provisions, those capacities should be based on the capacities either listed or determined in accordance with the ICC ES Report.*

2.3.2 Welding to these anchors is not permitted.

2.3.3 Screw anchors may be used to attach components, such as equipment, mechanical vibration isolators or snubbers, to structural (reinforced) concrete, or for sill bolting applications. All screw anchors installed through a wood sill plate requires a plate washer in conformance with Section 1806A.6.3, Item 2.

2.3.4 The use of screw anchors is not permitted in overhead applications or for discrete hold down forces, such as shear walls.

Commentary: *There is very little experience data on the performance of these anchors installed in the tension zone of concrete members. Until cracked concrete testing methods are adopted and incorporated into ICC Acceptance Criteria, similar to ACI 355.2, screw anchors cannot be used overhead. In addition, the high Rockwell hardness of some screw anchors may make them susceptible to hydrogen embrittlement.*

Screw anchors may be very effective in sill bolting applications to reduce the possibility of concrete splitting due to edge distance limitations, and a reduction or elimination of expansion pressures associated with bolt installation.

2.4 Power-actuated fasteners. Power-actuated fasteners (shot pins) are not addressed by Section 1923A.3.5, 2001 CBC. Power-actuated fasteners may be used for limited applications provided the allowable shear and tension loads are determined in accordance with the following:

2.4.1 The allowable values listed in an ICC ES Evaluation Services Report, with special inspection, may be used for allowable stress design, provided the report states that the anchors were tested in accordance with AC70, latest revision.

Power-actuated fasteners may be used for hanging metal suspension systems for lay-in panel ceilings (see IR 25-2) and for the attachment of metal track in conjunction with non-bearing partitions. The use of power-actuated fasteners for other applications shall be subject to review and approval of DSA.

3. EMBEDMENT, SPACING, AND EDGE DISTANCE. All anchors shall meet the minimum embedment, spacing, edge distance, and slab thickness criteria established by the relevant ICC-ES Report.

3.1 Unless otherwise noted in the Report, the edge distance should be a minimum of ten (10) bolt diameters from the free edge of the slab and center-to-center spacing should be a minimum of twelve (12) bolt diameters. If the edge distance is less than ten (10) diameters, and the load is directed toward the free edge, the allowable shear load should be reduced per Section 1923A.3.3.

4. UNDERSIDE OF BEAM/SLAB INSTALLATIONS. Except as noted in Section 2.1, all expansion type anchors installed in the underside of a beam/slab should use the reduced allowable design load values determined in Sections 2.1.1 and 2.1.2.2 of this IR.

4.1 The allowable design loads in Sections 2.1.1 or 2.1.2.1 may be used for expansion-type anchors installed in the underside of a beam/slab, provided the installation meets one of the following criteria:

4.1.1 The design engineer provides information that indicates the anchor installation will occur in the negative moment (-M) region of the beam/slab, considering unbalanced loading, or

4.1.2 Data is submitted to indicate that specific anchor is suitable for use in cracked concrete (testing per ACI 355.2, Table 5.2, including Annex 1 of AC193), or

4.1.3 The anchor is installed in the high flute (rib) of the metal deck in a concrete on metal deck assembly, or

4.1.4 The anchor is installed with sufficient embedment that the load transfer zone is above the neutral axis of the beam/slab.

Exception: If the slab is intended to serve as a diaphragm for transferring seismic forces to other lateral-load resisting elements, anchors to be installed must be qualified per 4.1.2 above or the reduced allowable design load values determined in Sections 2.1.1.1 and 2.1.2.1 must be used.

4.2 When installing expansion-type anchors through the low flutes of metal deck into concrete, the anchors should be placed as close to the center of the flute width as practicable. The deck shall be 20 ga. minimum thickness per CBC Section 2205A.4.1 and the flute width shall meet or exceed the value set forth in the ICC-ES Report for the anchor. The minimum effective depth of embedment shall be as noted in the ICC-ES Report for the anchor.

Commentary: *Several deck manufacturers' have a small rib that runs down the middle of the low flute of deck. This rib is problematic as the drill bit will have a tendency to "walk" down the rib. An offset in the hole is acceptable so long as the hole is as close as possible to the center of the deck.*

5. TESTING AND INSPECTION REQUIREMENTS. Post-installed anchors shall be tested in accordance with the provisions of Section 1923A.3.5, by an LEA accepted testing facility, unless approval of an alternative individual is obtained in advance from the DSA Field Engineer for the project.

If any anchor fails testing, test all anchors of the same type, not previously tested until twenty (20) consecutive anchors pass, then resume the initial test frequency. If the anchors are used for the support and bracing of non-structural components (pipe, duct or conduit), the twenty (20) shall be only those anchors installed by the same trade. Refer to Note 8 on the Test Values Table (attached) for acceptance/failure criteria.

Regardless of which test method is chosen by the consultant, test values and all appropriate criteria shall be shown on the contract documents.

5.1 Expansion-type Anchors

5.1.1 Setting verification:

5.1.1.1 Torque-controlled anchors: Following attainment of 10% of the required torque, torque-controlled anchors shall not require more than six (6) additional complete turns of the nut during installation to achieve the manufacturer's specified installation torque. The extent of bolt projection after installation shall be measured to confirm that this requirement has been met.

5.1.1.2 Displacement-controlled anchors: The position of the plug in the anchor shell shall be checked with the manufacturer-supplied installation tool or other appropriate device. The position of the plug shall conform to the manufacturer's specifications.

Commentary: *Torque-controlled anchors (wedge anchors, sleeve anchors) should be limited in the number of turns required to develop the specified installation torque. An excessive number of turns could indicate a failure to set and also reduces the effective embedment of the anchor. Most anchors should not require more than 2-3 turns (after the parts are snug) to set properly. The degree of bolt projection conforming to proper set should be established for the specific anchor being inspected. The tension performance of displacement-controlled anchors (drop-ins) depends in large part on the degree to which the plug is driven into the anchor shell during installation (i.e., the plug displacement).*

5.1.2 **Testing:** An acceptable testing procedure is attached to this IR. The test load may be applied by any method that will effectively measure the tension in the anchor, such as direct pull with a hydraulic jack, calibrated spring loaded devices, or a calibrated torque wrench. Displacement-controlled anchors such as drop-ins shall not be tested using a torque wrench.

Required test loads may be determined by either of the following methods:

5.1.2.1 Twice the allowable tension load as determined in Section 2, or;

5.1.2.2 Tension or torque test values from the table and procedures attached to this IR.

Anchors tested with a hydraulic jack should exhibit no discernable movement during the tension test, e.g., as evidenced by loosening of the washer under the nut.

Anchors tested with a calibrated torque wrench must attain the specified torque within 1/2 turn of the nut.

Exceptions: Undercut anchors that are so designed to allow visual confirmation of full set, need not be tension or torque tested.

If the manufacturer's installation torque is less than the specified test torque, use the manufacturer's specified installation torque for testing the anchor.

5.2 Epoxy-type (adhesive) Anchors

Epoxy-type (adhesive) anchors shall be tension tested per Section 1923A.3.5. The tension test load shall equal twice the allowable load for the specific location of the anchor to be tested (i.e., accounting for edge distance) or 80% of the yield strength of the bolt ($0.8A_bF_y$), whichever is less. The test procedures for expansion-type anchors in the attached table shall also be used for epoxy-type (adhesive) anchors. Torque testing of epoxy-type (adhesive) anchors is not permitted.

Where epoxy-type (adhesive) anchors are used as shear dowels across cold joints in slabs on grade and the slab is not part of the structural system, testing of those dowels is not required.

Anchors shall exhibit no discernible movement during the tension test.

5.3 Screw-type Anchors: Screw-type anchors shall be torque tested in accordance with the testing procedure attached to this IR.

Commentary: *Screw-type anchors that are installed improperly (either over tightened or over-sized holes) would typically exhibit excessive movement, or "spinning" in the hole at relatively low torque values. Tension testing of these anchors is not necessary as the testing procedure would require partial removal/withdrawal of the anchor to facilitate testing.*

TEST VALUES
Hardrock or Lightweight Concrete

ANCHOR	WEDGE		SLEEVE		SHELL		SCREW
Diameter (in.)	Load (lbs.)	Torque (Ft. lbs.)	Load (lbs.)	Torque (Ft. lbs.)	Load (lbs.)	Torque (Ft. lbs)	Torque (Ft. lbs.)
1/4	800	10	400	4	1000	-	-
5/16	-	-	400	5	1400	-	-
3/8	1100	25	700	10	1800	-	10
1/2	2000	50	900	20	2700	-	10
5/8	2300	80	1100	45	3700	-	10
3/4	3700	150	1400	90	5400	-	20
1	5800	250	-	-	-	-	-

NOTES

1. Anchor diameter refers to the thread size for the WEDGE & SHELL categories, and to the anchor outside diameter for the SLEEVE category.
2. Apply proof test loads to WEDGE & SLEEVE anchors without removing the nut if possible. If not, remove nut and install a threaded coupler to the same tightness as the original nut using a torque wrench to apply the test load.
3. For SLEEVE/SHELL internally threaded categories, verify that the anchor is not prevented from withdrawing by a baseplate or other fixtures. If restraint is found, loosen and shim or remove fixture(s) prior to testing.
4. Reaction loads from test fixtures may be applied close to the anchor being tested, provided the anchor is not restrained from withdrawing by the fixture(s).
5. SHELL type anchors should be tested as follows:
    a. Visually inspect 25% for full expansion as evidenced by the location of the expansion plug in the anchor body. Plug location of a fully expanded anchor should be as recommended by the manufacturer, or, in the absence of such recommendation, as determined on the job site following the manufacturer's installation instructions. At least 5% of the anchors shall be proof loaded as indicated in the table above, but not less than three anchors per day for each different person or crew installing anchors, or;
    b. Test installed anchors per Section 1923A.3.5
6. Test equipment (including torque wrenches) is to be calibrated by an approved testing laboratory in accordance with standard recognized procedures.
7. Alternate torque test procedures and test values for SHELL type anchors may be submitted to the enforcement agency for review and approval on a case-by-case basis when test procedures are submitted and approved by the enforcement agency.
8. The following criteria apply for the acceptance of installed anchors:
    a. HYDRAULIC RAM METHOD: The anchor should have no observable movement at the applicable test load. For wedge and sleeve type anchors, a practical way to determine observable movement is that the washer under the nut becomes loose.
    b. TORQUE WRENCH METHOD: The applicable test torque must be reached within the following limits:
        i. Wedge or Sleeve type: One-half (1/2) turn of the nut.
        ii. One-quarter (1/4) turn of the nut for the 3/8 in. sleeve anchor only.
9. If the manufacturer's recommended installation torque is less than the test torque noted in the table, the manufacturer's recommended installation torque should be used in lieu of the tabulated values.